ELSEVIER

CrossMark

Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 79 (2015) 506 – 512

Energy Procedia

2015 International Conference on Alternative Energy in Developing Countries and Emerging Economies

Does the use of Solar and Wind Energy Increase Retail Prices in Europe? Evidence from EU-27

Gyanendra Singh Sisodia[a*], Isabel Soares[b], Paula Ferreira[c],Sanjay Banerji[d], Dirk Van den Poel[e], Manish Kumar[f]

[a]*Amrita School of Business, Amrita University, Coimbatore, India; FEP, University of Porto, Portugal; and Department of Marketing, Faculty of Economics, Ghent University, Belgium*
[b]*CEFUP and FEP, University of Porto, Portugal*
[c]*DPS, University of Minho, Guimaraes, Portugal*
[d]*Amrita School of Business, Amrita University, Coimbatore, India*
[e]*Department of Marketing, Faculty of Economics, Ghent University*
[f]*Self employed, Ranchi, India*

Abstract

High technology and innovation market risk make renewable electricity generation expensive. On the other hand, green taxes applied to thermal generation also play a significant role in the increasing retail prices, considering that most energy systems are not completely renewable. The academic literature on the relationship between renewable electricity supply and electricity prices to final consumers suggest that a larger share of renewable electricity supply increases the price of electricity to end consumers although wind energy and solar energy have very low marginal costs. This study shows the individual contribution of solar and wind energy generation to the households and industrial electricity retail prices through panel data modeling of EU-27 (1995 to 2011). Random effect modeling was applied to understanding the net effect on prices. Independent variables include regulation perceptions, carbon emissions and levelised costs of electricity generation. The result of this study suggests that energy generation through wind and solar plays a negligible role in determining retail electricity prices to households, whereas in the case of industrial prices, their (solar and wind's) contribution is significant, but the value of the coefficient observed is close to zero.

Peer-review under responsibility of the Organizing Committee of 2015 AEDCEE

Keywords: renewable electricity; retail electricity price; household electricity price; panel data; solar energy; wind energy; renewable energy

* Corresponding author. Tel.: +32-46555-8968.
E-mail address: singh_gis@yahoo.co.in, ss_gyanendra@cb.amrita.edu.

1876-6102 © 2015 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the Organizing Committee of 2015 AEDCEE
doi:10.1016/j.egypro.2015.11.526

1. Introduction

Renewable energy has been considered as one of the key elements to address climate change issues due to global warming. It is included in the energy policy of major countries (for an instance, see [1] and [2]). This also encourages new economic sectors to reduce the energy dependency on traditional sources [3]. Existing literature on renewable energy supports the price increase of electricity in short run. However, the individual effect of electricity generation through solar and wind on retail electricity prices is yet not known in the literature. The purpose of this study is to determine the drivers of electricity prices for households and industries.

Moreno et. al. (2012) have considered four economic variables (including RES) to propose empirical models[4]. However, Moreno et. al. (2012) did not consider levelized costs of electricity generations. Levelised cost associated with electricity generation (although it may be subsidized) is an important consideration to model an investment empirically. This is particularly significant as businesses looking to make an investment in the electricity sector are also looking at levelised costs of available technologies (e.g. wind, solar, biomass, nuclear) [5][6]. Therefore, the present study is an attempt to develop a revised model that can give more information on other associated variables through panel data modeling. Thus, it intends to contribute to the body of current scientific knowledge of electricity investments and price drivers.

There can be an undesirable consequence of increasing renewable share in electricity generation, as it may increase retail electricity prices. Recently, Azofra et. al. (2014) examined the impact of biomass, solar, thermal and mini hydropower on electricity prices[7]. They applied Artificial Intelligence techniques to model the data, and the outcome of the study showed a negative relationship between electricity prices and power generation through the aforementioned sources. Contrary to the above study, Cai et. al. (2013) found that despite feed-in-tariffs and fixed rates of returns, higher solar installation (rooftop) leads to increase of electricity prices[8]. Similarly, Dinica (2011) shows how the operational cost of producing electricity through renewable energy sources varies with geographical, infrastructural, institutional and resource factors[9]. Finally, increased operational cost is passed on to consumers, thereby increasing the electricity prices. However, apart from the generation cost, other factors - market drivers, perceived regulatory quality, corruption, environmental pollution, etc. - may also influence the electricity price.

However, the impact of such variables on electricity price, as considered in this study, has not been studied earlier. Within the mandate of our study, we have asked the following two Research Questions (RQs)-

Research Question 1: Which are the determinants of retail electricity prices for households?

Research Question 2: How does investment in Renewable energy sources affect the retail prices of industrial sector?

To get the answer of our research questions, we kept our scope limited to testing the following hypotheses related to the generation of solar, wind electricity, carbon emissions, and regulatory framework.

H1a: Higher share of electricity generated through solar leads to higher electricity prices for households

H1b: Higher share of electricity generated through wind leads to higher electricity prices for households

H2a: Higher share of electricity generated through solar leads to higher electricity prices for industries

H2b: Higher share of electricity generated through wind leads to higher electricity prices for industries

H1c: Cleaner energy supply leads to higher electricity prices for households

H2c: Cleaner energy supply leads to higher electricity prices for industries

H1d: Stronger regulation perception leads to higher electricity price for households

H2d: Stronger regulation perception leads to higher electricity price for industries

Rest of the article is organized as follows: In section 2, data and methodology are shown and justified. The section 3 deals with modeling and empirical results and section 4 concludes the study.

2. Data and methodology

To address the above research questions, hypotheses were formulated and empirical model with two versions were developed. Data used was taken from Eurostat and World Bank. Finally, results were critically analyzed. EU-27[b] consists of 27 European countries and represents an adequate and varied sample.

Annual data from 1995 to 2011 was used from the World Bank and Eurostat database for EU-27 countries. The World Bank and Eurostat databases are considered to be a reliable source of information. The period chosen was also dictated by the availability of the data of solar and wind energy for the countries in the sample. A few of the variables that were directly used have random missing values, which was taken care of in the proposed macroeconomic model [10][11].

Data was identified in Eurostat for both the dependent variables. Each one has six-monthly data, and two six-monthly figures corresponding to same year were averaged for annual consideration. This had to be done to match the dependent variables with the other variables used as independent data available on an annual basis. Following the model adopted by Moreno et. al. (2012) [4], we prefer to use logarithmic values for retail electricity prices of household and industry instead of using directly available values. Given the high variation of taxes among countries, net electricity price before taxes was considered as the final do not reflect the true cost.

For the scope of the current study, medium sized households and medium sized industries were considered from the Eurostat database. For household electricity consumption, prices are measured as an average national price in Euro per KWh without taxes for the average of first & the second semester of each year for medium size household consumers (Consumption Band DC with annual consumption between 2500 KWh and 5000 KWh). These variables were also studied by Soares & Sarmento (2009)[12]; and similar kind of study was performed by Sisodia & Soares (2015) to find the drivers of renewable energy investments [13].

Independent variables are broadly classified as price variables, economic variables and other variables. "Price variables" comprise the levelised cost of electricity generation for wind (LW) and solar (LS) electricity, and electricity prices before taxes for households (EPH) and industries (EPI). Whereas "economic variables" are clubbed as CO2 emissions (CE), energy imports[c] (EI), GDP growth rate (GDPG), electricity generation (EG), RES through solar (RES-S) and wind (RES-W). A third broad section "other variables" - includes annual sunshine hours (ASH), and regulatory quality (RG). While testing hypotheses, and developing empirical models, independent variables were again reduced to follow the rules of econometrics [14].

Levelized cost of electricity generation through wind and solar were taken from the World Energy Outlook. According to EIA (2013), levelized costs are associated with competitiveness of generating electricity from different sources. EPH and EPI price to final consumers before taxes were taken from

[b] EU-27 consists of 27 European countries, excludes Crotia that has recently joined. Given that Europe is first mover in implementing renewable energy projects, and the diverse settings of regulatory systems, economic framework and geographical factors- this sample finds importance in understanding the causal relationship between determined independent variables and solar & wind energy generation.

[c] EI and GDPG were dropped in modelling because of their high associations with CE which is found in existing research works.

Eurostat database. Prices are influenced by local and national circumstances of electricity market regulations. Therefore, the implemented prices are not homogeneous in nature. For formulating model versions 1 and 2, both of these variables are considered to be dependent variables. Additionally, RES also has an impact on prices. These impacts are presented in the RES literature for the long and short runs [15].

Annual sunshine hours (ASH) is assumed to play a critical role in the generation of solar power. Energy generated through sun is apparently related to ASH of each country of the sample. Given the geographical diversities in EU-27, it was expected that the variable would play a significant role in the study. Current sample that includes 27 countries, 17 countries have annual sunshine hours above 1650 hours; 10 countries having annual sunshine hours less than 1650. Germany was kept as a reference, as it is a country where a solar PV generation is higher, although it has only around 1650 hours of ASH.

Regulatory quality (RG) is a world governance indicator taken from World Bank database. It reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. Originally, estimation of governance perception ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance. To make the values positive without effecting the scale, a value 2.5 was added, such that -2.5 becomes (-2.5+2.5=0) zero, and +2.5 becomes (+2.5+2.5=5) five. Thus the scale is re-formulated from 0 to 5 (weak to strong) to avoid negative values. RG was expected to play a positive role in the investment. RG was also expected to be associated with corruption. Although corruption control as a variable was not directly used in the model, but may have an impact on the results associated with RG. It is assumed that electricity market regulation is a subset of overall regulation perception. Therefore, RG is considered to be a proxy for electricity regulation perception.

Further, the following assumptions were made while developing the versions of the model, as they represent the actual European framework. First, price of solar PV and wind technology has been decreasing over a period due to the technology life cycle. Second, the goals of energy policy in Europe are towards a strict environmental concern (green energy). Third, there are no significant problems concerning grids (transmission and distribution). Fourth, investments on solar and wind each year are considered to be uninfluenced by previous year(s) investments. Fifth, most of the countries follow feed-in-tariff models, electricity by RES is 100% supplied to the grid.

3. Modelling and results

3.1. Empirical model

This section deals with modeling and empirical results. Once more, a survey of the literature on econometric modeling associated with renewable energy was considered. Results obtained in previous studies were considered to validate the findings. EPH, EPI were considered to be dependent variables. In earlier panel studies, electricity prices are used in logarithmic transformation [16][17].

Within the current scope of the study, the following two OLS regression models were used to understand the effects of independent variables.

$$\text{Log Yit (EPH)} = \beta0 + \beta1{*}LS + \beta2{*}LW + \beta3{*}\text{Lag }1{*}EPH + \beta4{*}CE + \beta5{*}EG + \beta6{*}RES\text{-}S + \beta7{*}RES\text{-}W + \beta8{*}ASH + \beta9{*}RG + Uit \quad (1)$$

$$\text{Log Yit (EPI)} = \beta0 + \beta1{*}LS + \beta2{*}LW + \beta3{*}\text{Lag }1{*}EPI + \beta4{*}CE + \beta5{*}EG + \beta6{*}RES\text{-}S + \beta7{*}RES\text{-}W + \beta8{*}ASH + \beta9{*}RG + Uit \quad (2)$$

where i = 1,.,27, t = 1995,.,2011, and β0 parameters denote country effects which are included in the model in order to take account of any possible country-specific factors that may have an influence on prices beyond the explanatory variables included. The disturbance of this model is denoted by Uit and is assumed to be independently and identically distributed random variables with mean zero and variances σ2u.

Further, RES market is considered to be a dynamic market in the current context with several new businesses coming in and increasing the competition in the sector [18]. Investment in RES in a particular year may not be dependent on investment in the previous year. In order to understand which panel model is suitable for data modeling, Hausman test was performed. P value in our case is higher than 0.5, and it suggests that a random effect model better suit to address the study.

3.2. Results and discussions

The results of the study are shown in table 1. The primary consideration for the study is the relevance of independent and dependent variable identified through the literature and determination of coefficient values and their levels of significance. In our analysis, we observe very high R-squared values for Model version 1 & 2 as 0.91 and 0.86 respectively, which indicates the model fit by 91 and 86 % for electricity prices of households and industries respectively.

Table 1: Proposed model versions (MV)

		Log(EPH) MV 1		Log(EPI) MV 2	
Price variables	LS	0		0	
	LW	0		0	
	Lag EPH (-1)	0.879	*		
	Lag EPI (-1)			0.847	*
Economic variables	CE	-0.109	**	-0.174	*
	EG	0		0	**
	RES-S	0	***	0.002	***
	RES-W	0		0.002	**
Other variables	ASH	-0.007		-0.009	
	RG	0.017		-0.035	
R-squared		0.918		0.863	
Adjusted R-squared		0.915		0.859	
F-statistic		315.985		176.337	
Prob(F-statistic)		0		0	

*significant at 1% level
**significant at 5% level
***significant at 10% level

On the one hand, the electricity market is highly sensitive to regulatory policies. That means higher regulatory quality is usually perceived with higher formalities and more taxes, which can be offset in the short run by offering bribes to the regulators [19][20]; on the other hand, strong regulations could also impose stronger norms for electricity distribution and dissemination by adding cost to the distributors. This cost would be passed to consumers and make electricity more expensive. On the other hand, lower quality of the regulation could also be associated with smaller and easier formalities because of which the business investment is trouble-free. In spite of unethical practices, this may also mean more competition in the market. Moreover, the likelihood of higher investment in countries with better regulatory quality could also be due to their tougher environmental policies. Such stringent environmental policies give the business opportunity to align with the aim of government, and this could lead to increase the investment.

In model version 1, wind and solar energies were expected to influence the prices of households. However, it is observed that RES-S play a significant role in determining household electricity prices, but coefficient is not impressive (table 1) and RES-W does not play a significant role in determining household electricity retail prices. Electricity generated through RES-S and RES-W is sold in the electricity market at wholesale price. Suppliers later redistribute electricity, through networks to households. Also, final electricity bill frequently includes other costs and taxes, related to the electricity system; for example high voltage transportation, medium and low voltage distribution, green fees, VAT, municipal charges and other costs designated by the government. Therefore, variations between wholesale and retail prices might not be explained well through the model version. However, distribution and supply cost is expected to affect the retail price significantly. It would also be important to understand if the reduction of conventional fuels resulted in an increase of the electricity prices; a separate study is proposed to understand the phenomenon.

It is seen that household price of electricity shows a critical and significant (at 1% level) relation with lagged electricity prices (1year) with a coefficient of 0.87. But, no significant relationship is observed for LS, LW, EG, ASH and RG. However, a statistically significant (at 5% level) and negative relationship with a coefficient of -0.1 is observed for carbon emissions; which can mean that the cleaner the energy, the higher the price customers have to pay, in the short run. Clean energy represents the energy that is generated through lower carbon emission as compared to conventional sources.

In model version 2, determinants of electricity prices for industry (EPI) are found to be insignificant for LW and LS; CE is negative with a factor of -0.17 and significant at the 1% level. The results obtained are similar to results obtained by Paul et. al. (2013) and Mulder et. al. (2013). They found a positive relationship between electricity prices and RES generation which reinforce that the cleaner the energy is, the higher the price customers have to pay in the short run.

4. Conclusions

This study covered the macro perspective over a big sample. Assuming that the results can be extrapolated to for most of the EU states, outcome of result has a broad policy implication at EU level. As a matter of policy and uncertainty in regulatory framework, it would be important for investors to actually recognize that soon solar and wind energy generating technologies would be recognized as “mature”, and there would be no support schemes towards wind and solar plants; or government in few countries may even be proactively supporting the generation that doesn’t affect the final electricity price. However, it is emphasized that the final outcome of energy policies strongly depend on the evolution of fossil fuel prices, as its increase in the future can result in higher impact on the retail prices for both households and industry either directly or through the imposition of green taxes.

The results demonstrate that the European energy policy requires a systematic approach towards a cost-efficient integration of RES, recognizing the possibility of direct supporting systems combined with incentives for technology development, management strategies such as demand side management or balanced geographical distribution as recently described in KEMA consulting (2014)[21]. This approach should contribute to the investors’ interest and confidence in the projects, but should also ensure that it will not result in a significant increase of the consumer’s bill.

Since EU-27 represents a large sample with diverse countries; the results generated could be widely affected by individual variations. Therefore, a next study conducted on a smaller sample of EU-15 or homogeneous countries will lead to a further understanding of the variations in results across large and small samples.

References

[1] IEA. World Energy Outlook. International Energy Agency, Paris; 2012.

[2] IPCC. Renewable energy sources and climate change mitigation. Special report of the intergovernmental panel on climate change (Geneva); 2011.

[3] Würzburg K, Labandeira X, Linares P. Renewable generation and electricity prices: Taking stock and new evidence for Germany and Austria. *Energy Economics* 2013, 40, 159–171.

[4] Moreno B, López AJ, García-Álvarez MT. The electricity prices in the European Union. The role of renewable energies and regulatory electric market reforms. Energy 2012; 48(1), 307–313.

[5] Gross R, Heptonstall P, Blyth W. *Investment in electricity generation: the role of costs, incentives and risks*. A report produced by Imperial College Centre for Energy Policy and Technology (ICEPT) for the Technology and Policy Assessment Function of the UK Energy Research Centre; 2007

[6] VGB Report. Investment and Operation Cost Figures – Generation Portfolio; 2011.

[7] Azofra D, Martínez E, Jiménez E, Blanco J, Saenz-Díez JC. Comparison of the influence of biomass, solar–thermal and small hydraulic power on the Spanish electricity prices by means of artificial intelligence techniques. *Applied Energy* 2014, 121, 28–37. [8] Cai DWH, Adlakha S, Low SH, De Martini P, Mani Chandy K. Impact of residential PV adoption on Retail Electricity Rates. *Energy Policy* 2013, 62, 830–843.

[9] Dinica V. Renewable electricity production costs—A framework to assist policy-makers' decisions on price support. *Energy Policy* 2011, 39(7), 4153–4167.

[10] Dragset IG. *Analysis of Longitudinal Data with Missing Values*. Norwegian University of Science and Technology; 2009. Retrieved from http://www.diva-portal.org/smash/get/diva2:348872/FULLTEXT01.pdf Dated December 12, 2013

[11] Wang W, Lee L. Estimation of spatial panel data models with randomly missing data in the dependent variable. *Regional Science and Urban Economics* 2013, 43(3), 521–538.

[12] Soares I, Sarmento P. Telecommunications, Electricity and Natural Gas Sector Unbundling: how far should it go? Second annual conference on competition and regulation in network industries; 2009. Retrieved fromhttp://www.crninet.com/2009/2009%20cni%203c.pdf Downloaded on March 18, 2014

[13] Sisodia GS, Soares I. Panel data analysis for renewable energy investment determinants in Europe. *Applied Economics Letters* 2015, 22(5), 397-401

[14] Arceneaux K, Huber GA. What to Do (and Not Do) with Multicollinearity in State Politics Research. *State Policy and Quarterly Reviews* 2007, 7(1), 81.

[15] Hughes G, Barnett L. The impact of wind power on household energy evidence to the house of commons. The Global Warming Policy Foundation 2012, (4).

[16] Aiube FL, Baidya, TKN, Blank FF, Mattos AB, Saboia W, Siddiqui AS. Modeling Hourly European Electricity Spot Prices via a SARMA-GARCH Approach. *Working Paper of Stockholm University* 2013, (260041), 1–46.

[17] Serati M, Manera M, Plotegher M, Lavoro NDI, Plotegher M, Eni F, Mattei E. Modeling Electricity Prices : From the State of the Art to a Draft of a New Proposal. *International Energy Markets* 2008.

[18] Peter F. Energy expert "Renewables can compete" Environment DW; 2013.

[19] Worldbank Report, 1997.

[20] Johnson S, Kaufmann D, Zoido-Lobaton P. Regulatory Discretion and the Unofficial Economy. *American Economic Review* 1998, (May).

[21] Kema Consulting. Integration of Renewable Energy in Europe; 2014. Retreived from http://ec.europa.eu/energy/renewables/doc/201406_report_renewables_integration_europe.pdf date September 15, 2014.